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Description of the helminth communities of sympatric rodents (Muroidea: Cricetidae) from the Atlantic Forest in northeastern Argentina

GUILLERMO PANISSE[1], MARÍA DEL ROSARIO ROBLES[1, 4], MARÍA CELINA DIGIANI[2], JULIANA NOTARNICOLA[3], CARLOS GALLIARI[1] & GRACIELA TERESA NAVONE [1]

[1]*Centro de Estudios Parasitológicos y de Vectores UNLP-CONICET. Boulevard 120 Nro 1460 e/61 y 62 (B1902CHX) La Plata—Buenos Aires—Argentina. E-mail: rosario@cepave.edu.ar*
[2]*CONICET. División Zoología Invertebrados, Museo de la Plata Paseo del Bosque s/nº -B1900FWA—La Plata—Buenos Aires—Argentina.*
[3]*Instituto de Biología Subtropical UNaM-CONICET. Bertoni 85, 3370 Puerto Iguazú—Misiones—Argentina.*
[4]*Corresponding author*

Abstract

Taxonomic and ecological aspects of the helminths found in the assemblage of sigmodontine rodents (Cricetidae-Muroidea) of the Atlantic Forest in Argentina are studied in this paper. The following species *Akodon montensis*, *Brucepattersonius* sp. and *Thaptomys nigrita* (Tribe Akodontini), as well as, *Euryoryzomys russatus*, *Nectomys squamipes*, *Oligoryzomys nigripes*, and *Sooretamys angouya* (Tribe Oryzomyini) are analyzed. A complete taxonomic list with a total of 25 species of helminths, including Digenea (Dicrocoeliidae), Cestoda (Hymenolepididae) and Nematoda (Trichuridae, Capillariidae, Cooperidae, Helligmonellidae, Oxyuridae, and Onchocercidae) is provided. Twenty new host and locality records for Misiones, Argentina, are reported and the results of the ecological descriptors of component communities are given. The highest value of richness was observed for *A. montensis* (S=8) and *E. russatus* (S=7). The diversity index (H´) reached values between 1.03 and 1.39 in all rodents, with the exception of *N. squamipes* that reached 0.75. The equitability indeces with highest value were observed for *T. nigrita* and *E. russatus*. The Berger-Parker index of dominance was similar for all host species. The highest prevalence, mean abundance and mean intensity values corresponded to Nippostrongylinae, followed by Syphacinii. This survey constitutes the report with the most diverse parasitic assemblage of rodents described for the Atlantic Forest ecoregion and for Argentina.

Key words: Digenea, Cestoda, Nematoda, Sigmodontinae, Misiones, Argentina

Introduction

Interactions between mammals and their parasites occur within a complex network of ecological relations and provide an opportunity for new adaptation and even new evolutionary traits (Morand *et al*. 2006).

The breadth and composition of the diet, as well as, the behaviour of hosts affect directly the parasite richness. Host features influence parasite species richness, possibly facilitating the acquisition of new parasites via host-switching. Specifically, hosts with broad geographical ranges inhabit a wider variety of habitats determining a higher exposure to a novel parasite than those hosts with more restricted geographical ranges (Poulin & Morand 2004). Moreover, parasite species richness generally shows phylogenetic conservatism since two related host species tend to harbour more similar parasite faunas than two distantly related hosts. However, ecological properties play an independent role in determining whether few or many parasite species can exploit a given host species. Indeed, in many taxa of hosts, interspecific variation in parasite species richness appears to follow the variation in host species traits or in the characteristics of their habitats (e.g., Nunn *et al*. 2003; Lindenfors *et al*. 2007; Bordes *et al*. 2009; Poulin 2014).

The subfamily Sigmodontinae constitutes the most diverse South American group of Cricetidae rodents (Reig 1986). This subfamily is endemic to the American continent and includes around 86 living genera and about 400

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living species, of which 85 genera and 381 species inhabit South America (Patton *et al.* 2015). These rodents dwell in almost all types of habitats found in their geographical range, including deserts, wet tropical and temperate forests, scrublands, wetlands, savannas, steppes, high elevation grasslands and salt flats (Hershkovitz 1962).

In Argentina, about 105 species, grouped in 38 genera, are recognized (Galliari *et al*. 1996; Pardiñas *et al*. 2006). The Atlantic Forest has one of the most diverse assemblages of sigmodontine rodents (Placi & Di Bitetti 2006; Barquez *et al*. 2006). The most frequent species found in these assemblages are *Akodon montensis* Thomas 1913 (Akodontini) and *Oligoryzomys nigripes* (Olfers 1818) (Oryzomyini) with 75% of total abundance. Other species, such as *Thaptomys nigrita* (Lichtenstein 1829), *Brucepattersonius iheringi* (Thomas 1896) and *Euryoryzomys russatus* (Wagner 1848) are scarce in the ecoregion (Crespo 1982; Pereira *et al*. 2005; Cirignoli *et al*. 2011; Patton *et al.* 2015; Pardiñas *et al*. 2016).

There are numerous contributions in this country based on descriptions of helminths species poorly known in sigmodontine rodents and most of them correspond to nematodes (e.g. Sutton 1974, 1983, 1994; Suriano & Navone 1992, 1994, 1996; Notarnicola *et al*. 2000, 2002, Robles & Navone 2007 a; b; 2010; Notarnicola *et al*. 2010; Notarnicola & Navone 2011; Robles *et al.* 2008; 2012; Digiani *et al*. 2012; 2013; Notarnicola *et al.* 2012; Digiani & Kinsella 2014; Digiani *et al*. 2015; Robles *et al*. 2016).

The assemblages of parasites in Muridae rodents were studied in different areas of Europe and Africa (Fuentes *et al*. 2004; Behnke *et al*. 2004, 2008). In South America, helminths from Cricetidae rodents were studied by Gomes *et al*. (2003) and Simões *et al*. (2011, 2012a) in five host species from the Atlantic Forest in Brazil and by Navone *et al*. (2009) in six host species from the wetlands of the Río de La Plata in Argentina.

The aim of this study was to analyze the taxonomic and ecological aspects of the helminths found in the assemblage of sigmodontine rodents (Cricetidae-Muroidea) of the Atlantic Forest in Argentina.

Material and methods

Study area. The Interior Atlantic Forest of Argentina is located on the basaltic massif of Serra Geral with altitudes reaching 800 m.a.s.l. in the northeast of the province of Misiones, between Paraná and Uruguay rivers (Burkart *et al*. 1999; Placci & Di Bittetti 2005). The weather is warm and humid. The average annual temperature is 20º C with annual precipitations between 1800-2000 mm.

Samples were collected between September 2011 and August 2013 in the localities of Campo Anexo Manuel Belgrano, INTA San Antonio (CAMB) (26º03´S, 53º46´W); Reserva de Vida Silvestre Urugua-í (RVSU) (25º 58´S, 54º 07´W) and Parque Provincial Urugua-í (PPU) (25°58´S, 54°06´W), Misiones, Argentina. The trapping was carried out over the period of 23 days during the fall and winter with a sampling effort of 4086 trap nights (sampling effort of 1088 nights trap in 2011, 1200 in 2012, 2298 in 2013) (Jones *et al.* 1996).

The research was conducted in compliance with Argentine laws. Sample collection was carried out during fieldwork under official permits granted by the Ministerio de Ecología, RNR y Turismo, Provincia de Misiones (authorization #23, Guía Tránsito 000685 and 000699). This study was made following the recommendations in the Guide for the Care and Use of Laboratory Animals of the National Institutes of Health. The specimens, obtained using methods for live capture, were studied and sacrificed (by hypoxia due to disruption of vital centers) following the procedures and protocols suggested by AVMA Guidelines on Euthanasia (2007) and approved by national laws (Animal Protection National Law 14.346 and references in the provincial permits) and by the Ethics Committee for Research on Laboratory Animals, Farm and Obtained from Nature of the National Council of Scientific and Technical Research (CONICET) and, subsequently, by the National Agency for the Promotion of Science and Technology of Argentina (ANPCYT) (PICT 2010-0924). No endangered species were involved in this study.

Examination of rodents and study of parasites. Viscera were divided in digestive tract, liver, pancreas, heart, lungs and kidneys, and examined using a stereoscopic microscope (Leica MZ6 and Olympus SZ). Parasites were fixed in 10% formaldehyde and preserved in 70 % alcohol. Helminths were identified following the keys from Anderson *et al*. (2009) and Gibbons (2010) for Nematoda, Bray *et al*. (2008), Gibson *et al*. (2002) and Jones *et al*. (2005) for Trematoda, and Khalil *et al.* (1994) for Cestoda, among other specific literature. The nomenclature about the family group and use of terms for the Strongylida (Nematoda) follow Durette-Desset & Chabaud (1993) and Durette-Desset & Digiani (2012). The Capillariidae systematics follows Moravec (2001).

Helminth specimens were deposited in the Helminthological Collection of the Museo de La Plata (MLP-He),

La Plata, Buenos Aires. Rodent specimens are currently in the process of being deposited in the Mammal Collection of the Centro Nacional Patagónico (CNP), Puerto Madryn, Chubut, and are mentioned in this manuscript by their field number (CG or ROB).

Data analysis. The prevalence (P), mean intensity (MI) and mean abundance (MA) of each component population were calculated following Bush *et al*. (1997).

The specific richness (S), the Shannon & Wiener diversity index (H'), the Shannon equitability index (E) and the simple dominance index of Berger-Parker (D) (Magurran, 2004) were calculated for each component community, except for *Brucepattersonius* sp, using the PAST program of Hammer *et al*. (2001).

Results

The information is presented in the form of a list of helminth species. For each species, host records, site of infection, locality records and comments are provided.

A total of 168 rodents were examined, corresponding to the following species: *Akodon montensis* (n=104), *Brucepattersonius* sp. (n=7) and *Thaptomys nigrita* (n=6) (Tribe Akodontini); *Euryoryzomys russatus* (n=15), *Nectomys squamipes* (Brants, 1827) (n=3), *Oligoryzomys nigripes* (n=27) and *Soretamys angouya* (Fischer, 1814) (n=6) (Tribe Oryzomyini).

A total of 25 species of helminths, including Digenea (Dicrocoeliidae), Cestoda (Hymenolepididae) and Nematoda (Trichuridae, Capillariidae, Cooperidae, Helligmonellidae, Oxyuridae, and Onchocercidae) were mentioned. Twenty new host and locality records for Misiones, Argentina, were reported (Table 1).

List of heminth species

Phylum Platyhelminthes

Class Trematoda Rudolphi 1808

Subclass Digenea Carus 1863

Superfamily Gorgoderoidea Looss 1899

Family Dicrocoeliidae Looss 1899

Subfamily Leipertrematinae Yamaguti 1958

***Platynosomoides* sp.**

Site of infection. small intestine, bile duct

Collection number. MLP-He 7324

Host species. *Akodon montensis.* CG 169

Localities: RVSU and PPU

Comments. The morphological characters observed in the specimens agree with the description given by Yamaguti (1971) of the genus *Platynosomoides*, i.e. long and narrow caeca, reaching far beyond middle of body; testes posterolateral to ventral sucker; median genital pore anterior to intestinal bifurcation; ovary posterior to testes and vitelline glands forming lateral bands starting at level of ventral sucker.

The genus *Platynosomoides* sp. has not been mentioned parasitizing sigmodontine rodents until today. However, it was recorded for *Leopoldamys siporanus* Thomas 1895 (Muridae) in Asia (Malaysia, Armenia and Daguestan, Russian Federation) and for *Crocidura olivieri* (Lesson 1827) (Soricidae) in Africa (Democratic Republic of the Congo) (Pojmańska 2008).

This is the first record of the genus for South America.

TABLE 1. Previous and new records from hosts and areas of helminths from Sigmodontinae rodents.

Species	Host species This paper	Localities This paper	Host species Previous records	Province/States Country Previous records	References
Dicrocoellidae					
Platynosomoides sp.	*A. montensis**	RVSU, PPU; Argentina*			Present Study
Hymenolepididae					
R. cf. *akodontis*	*A. montensis*	RVSU PPU; Misiones*	*A. cursor*, *A. montensis*, *N. lasiurus*, *O. nigripes*, *O. rufus*	ES, RJ, Brasil.	Rêgo 1967; Simões *et al.* 2011
Trichuridae					
T. baine	*S. angouya*	RVSU, PPU*	*S. angouya*	MIS,FOR, Argentina	Robles *et al.* 2014;
T. navonae	*A. montensis*, *T. nigrita*	PPU	*A. montensis*, *T. nigrita*	MIS, Argentina	Robles 2011; Robles *et al.* 2014
T. cf. *travassosi*	*N. squamipes**	RVSU*, Argentina*	*O. nigripes*	RJ, Brasil	Gomes *et al*. 1992
Trichuris sp.	*E. russatus**	PPU*			
Capillariidae					
Eucoleus sp. (1)	*A. montensis**	RVSU*			Present Study
Eucoleus sp. (2)	*Brucepattersonius* sp.*	PPU*			Present Study
Cooperidae					
T. coronatum	*A. montensis*,* *E. russatus**, *O. nigripes**, *S. angouya**	CAMB, RVSU, PPU; Misiones*	*Holochilus brasiliensis*, *Tapirus terrestris*	BUE, Argentina; French Guiana	Durette-Desset *et al.* 1997
Helligmonellidae					
G. ulysi	*E. russatus**, *S. angouya*	RVSU, PPU*	*S. angouya*	MIS, Argentina	Digiani *et al.* 2012
G. zetta	*O. nigripes*	CAMB*, RVSU, PPU*	*A. cursor*, *E. russatus*, *N. squamipes*, *Cerradomys subflavus*, *O. nigripes*, *Galea spixii*	BA, GO, RG, RJ, Brasil; MIS, Argentina	Travassos 1937; Pinto *et al.* 1982; Gomes 2003; Simões *et al.* 2011; Digiani *et al.* 2012; Simões *et al.* 2012; de Werk *et al.* 2016
H. epsilon	*N. squamipes*, *O. nigripes**	CAMB, RVSU, PPU; Argentina*	*A. cursor*, *N. squamipes*	GO, RJ, Brasil	Travassos 1937; Durette-Desset 1971; Pinto *et al.* 1982; Gomes *et al.* 1984; Maldonado *et al.* 2006

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TABLE 1. (Continued)

Species	Host species This paper	Localities This paper	Host species Previous records	Province/States Country Previous records	References
T. lenti	*A. montensis*	CAMB, RVSU, PPU; Misiones*	*A. cursor*, *A. montensis*, *A. simulator*, *O. flavescens*, *O. nigripes*,	RJ, Brasil; BUE, TUC, Argentina;	Sutton & Durette-Desset 1991; Suriano & Navone 1992; Digiani *et al.* 2007; Simões *et al*. 2011
S. aculeata	*A. montensis*	CAMB*, RVSU*, PPU*; Argentina*	*A. cursor*, *A. montensis*	RJ, Brasil	Travassos 1937; Gomes 2003; Simões *et al.* 2011
S. lanfrediae	*E. russatus**, *O. nigripes* , *S. angouya**,	CAMB*, RVSU*, PPU*; Argentina*	*A. cursor*, *A. montensis*, *O. nigripes*	RJ, Brasil	Souza *et al.* 2009, Simões *et al.* 2011
Stilestrongylus n. sp. (1)	*T. nigrita**	CAMB*, RVSU*, PPU*; Argentina*			Present Study
Stilestrongylus n. sp. (2)	*E. russatus**, *S. angouya**	CAMB*, RVSU*, PPU*; Argentina*			Present Study
Genus and species indet. (1)	*T. nigrita**	CAMB*, RVSU*, PPU*			Present Study
Genus and species indet. (2)	*E. russatus**	CAMB*, RVSU*, PPU*			Present Study
Oxyuridae					
S. alata	*T. nigrita*	CAMB*, RVSU, PPU*	*N. lasiurus*, *T. nigrita*	PE, Brasil; MIS, FOR, COR, SAN, BUE, Argentina	Quentin 1968, 1969; Robles 2008, 2010
S. carlitosi	*A. montensis*	CAMB, RVSU, PPU*	*A. azarae*, *A. montensis*, *A. philipmyersi*	RJ, Brasil; MIS, Argentina	Robles & Navone 2007; Robles 2010; Simões *et al.* 2011
S. evaginata	*E. russatus**	RVSU, PPU; Argentina*	*Oryzomys sp.*	BE, Brasil	Hugot & Quentin 1985
S. kinsellai	*O. nigripes*	CAMB*, RVSU*, PPU*	*O. nigripes*	MIS, Argentina	Robles & Navone 2007
S. venteli	*N. squamipes*	RVSU*	*N. squamipes*	RJ, Brasil; MIS, Argentina	Travassos 1937; Robles & Navone 2010
Onchocercidae					
L. navonae	*N. squamipes*, *O. nigripes**	CAMB*, PPU*	*A. azarae*, *H. chacarius*, *N. squamipes*, *O. chacoensis*, *O. fornesi*	FOR, CHA, MIS, Argentina	Notarnicola 2005

(*) New record for host or locality. Province/State: BA: Bahía, BE: Belem, BUE: Buenos Aires, CHA: Chaco, COR: Corrientes, ES: Espirito Santo, FOR: Formosa, GO: Goiás, MIS: Misiones, PE: Pernambuco, RG: Rio Grande do Sul, RJ: Rio de Janeiro, SAN: Santa Fe, TUC: Tucumán

Class Cestoda

Subclass Eucestoda

Order Cyclophyllidea van Beneden in Braun 1900

Family Hymenolepididae Ariola 1899

***Rodentolepis* cf. *akodontis* Rêgo, 1967**

Site of infection. small intestine

Collection number. MLP-He 7325

Host species. *Akodon montensis*. CG169

Localities: RVSU and PPU

Comments. The morphological characters observed in the specimens agree with the original description given by Rêgo (1967), especially regarding the shape and length of hooks in the rostellum. However, some differences were noticed as for the length and width of scolex, length of rostellum, diameter of suckers, length of cirrus pouch and diameter of eggs. These morphometric differences can be attributed to a greater number of specimens studied.

Rodentolepis akodontis was described parasitizing *Necromys lasiurus* (Lund 1840) (= *A. arviculoides*) (Rêgo 1967) and later parasitizing *A. montensis*, *Akodon cursor* Winger, 1887 and *O. nigripes* in Brazil (Simões *et al*. 2011).The latter reports did not include morphological data. Guerreiro Martins *et al.* (2014) reported *Rodentolopis. cf. akodontis* from *Oxymycterus rufus* (Fischer 1814) in several localities extending from the province of Corrientes to the province of Buenos Aires, Argentina.

This finding enlarges the geographical distribution of *R. cf. akodontis* including the province of Misiones in Argentina.

Phylum Nematoda Rudolphi 1808

Class Adenophorea Chitwood 1958

Order Enoplida Baird 1853

Superfamily Trichinelloidea Ward 1907

Family Trichuridae Ransom 1911

***Trichuris bainae* Robles, Cutillas, Panei & Callejón, 2014**

Site of infection. caecum

Collection number. MLP-He7354

Host species. *Sooretamys angouya.* CG185

Localities. RVSU and PPU

Comments. The morphological characters observed in the specimens agree with the original description given by Robles *et al*. (2014), i.e. males without spicular tube, proximal cloacal tube united laterally to distal cloacal tube, cylindrical and spiny spicular sheath, and females with protrusive and ornamented vulva, among other morphometric features.

This species was described for the same host from Refugio Moconá Reserva de Usos Múltiples Guaraní, Misiones province and Estación de Animales Silvestres Guaycolec, Formosa province, Argentina.

***Trichuris navonae* Robles, 2011**

Site of infection. caecum

Collection number. MLP-He7326, MLP-He7333

Host species. *Akodon montensis*. CG145. *Thaptomys nigrita.* CG355

Localities. CAMB, RVSU and PPU

Comments. The morphological characters observed in the specimens agree with the original description given by Robles (2011), i.e. males without spicular tube, proximal cloacal tube united laterally to distal cloacal tube, cylindrical and spiny spicular sheath, and females with non-protrusive vulva, among other morphometric features.

This species was described for *A. montensis* and *T. nigrita* from different localities of Misiones province: Balneario Municipal de Aristóbulo del Valle of stream Cuña Pirú, Club Pesca Paranay-Guazú, mouth stream Paranay-Guazú, Stream Salamanca, Salto El Paraíso, Stream Paraíso, Stream Oveja Negra, Parque Provincial Cruce Caballero, Parque Provincial Moconá, Puerto Península (Robles 2011; Robles & Navone 2014).

Trichuris cf *travassosi* Gomes, Lanfredi, Pinto & De Souza, 1992

Site of infection. caecum

Collection number. MLP-He7345

Host species. *Nectomys squamipes.* CG44

Locality. RVSU

Comments. The morphological characters observed in the two male specimens collected agree with the original description given by Gomes *et al*. (1992), i.e. males without spicular tube; proximal cloacal tube united laterally to distal cloacal tube and cylindrical spicular sheath with spines irregularly distributed.

This species was described for *O. nigripes* from Arvorezinha, State of Rio Grande do Sul, Brasil (Gomes *et al*. 1992).

This is the first record of the genus *Trichuris* in *N. squamipes* and T. cf. *travassosi* for Argentina.

Trichuris sp.

Site of infection. caecum.

Collection number. MLP-He7337

Host species. *Euryoryzomys russatus*. CG563

Locality. PPU

Comments. The morphological characters observed in the two female specimens collected agree with the description of the genus *Trichuris*, i.e. anterior part of body being long, narrow, tapered and whip-like; posterior part of body being broad and handlelike with bacillary band located in anterior portion of body (e.g. Robles, 2011). These specimens show a nonprotrusive vulva, oval and flat eggs with bipolar plugs. More material should be collected to identify them at species level.

This is the first record of the genus *Trichuris* in *E. russatus*.

Family Capillariidae Railliet 1915

Eucoleus sp. (1)

Site of infection. small intestine

Collection number. MLP-He7327

Host species. *Akodon montensis*. CG145

Localities. PPU and RVSU

Comments. The morphological characters observed in the specimens agree with the description of the genus *Eucoleus*, i.e. males without caudal alae, distal end with two small, posteriorly directed rounded lobes and connected by a reduced membrane, spinous spicular sheath, and females with non-elevated vulva. Nevertheless, the material collected is not well conserved to allow identification at species level. It is to be noted that the

specimens were found in the small intestine, despite being the stomach the most common site of infection of the genus (Moravec, 1982).

This is the first record of the genus *Eucoleus* in *A. montensis* and the second record for Argentina (Robles *et al*. 2008).

***Eucoleus* sp. (2)**

Site of infection. stomach

Collection number. MLP-He7332

Host species. *Brucepattersonius* sp. CG140

Locality. PPU

Comments. The specimens were identified as *Eucoleus* by the morphological characters mentioned above and even though the material collected was not well conserved to allow identification at species level. This species differs from *Eucoleus* sp. (1) as to the presence of a single bacillary band and the length of the spicule, among other morphometric features.

This is the first record of the genus *Eucoleus* sp. (2) in *Brucepattersonius* sp. and the third record for Argentina (Robles *et al.* 2008).

Order Strongylida Diesing 1851

Suborder Trichostrongylina (Leiper, 1908, subfam.)

Superfamily Trichostrongyloidea (Leiper, 1908)

Family Cooperiidae (Skrjabin & Schulz, 1937)

Subfamily Obeliscoidinae Durette-Desset, 1999

***Tapironema coronatum* Durette-Desset, Chabaud & Sutton, 1997**

Site of infection. stomach

Collection number. MLP-He7328, MLP-He7338, MLP-He7348, MLP-He7355

Host species. *Akodon montensis.* CG169. *Euryoryzomys russatus*. CG563. *Oligoryzomys nigripes*. CG510. *Sooretamys angouya*. CG46.

Localities. CAMB, RVSU and PPU

Comments. The morphological characters observed in the specimens agree with the original description given by Durette-Desset *et al.* (1997), i.e. presence of a *corona radiata* and esophageal tooth, synlophe with numerous longitudinal ridges transversally elongated, caudal bursa with rays 5 and 6 apposed in males and didelphic in females.

Tapironema coronatum was described parasitizing *Holochilus brasiliensis* (Desmarest, 1819) (Rodentia: Sigmodontinae) in Buenos Aires province, Argentina, and parasitizing *Tapirus terrestris* (Linneaus, 1758) (Perissodactyla: Tapiridae) in French Guiana.

This finding enlarges the host records and adds new localities for Argentina.

Superfamily Heligmosomoidea Travassos, 1914

Family Heligmonellidae Skrjabin & Schikobalova, 1952

Subfamily Nippostrongylinae Durette-Desset, 1971

***Guerrerostrongylus ulysi* Digiani, Notarnicola & Navone, 2012**

Site of infection. small intestine

Collection number. MLP-He7339, MLP-He7356

Host species. *Euryoryzomys russatus*. CG563. *Sooretamys angouya*. CG201

Localities. RVSU and PPU

Comments. The morphological characters observed in the specimens agree with the original description given by Digiani *et al*. (2012), i.e. synlophe with numerous (ca. 40) subequal ridges, heart-shaped caudal bursa with hypertrophied dorsal ray and longer than rays 6, rays 6 shorter than rays 8, straight and weakly sclerotized spicules and 6.4–9.5% mean the proportion (in percentage) of spicule length on body length (SpL/BL).

Digiani *et al*. (2012) gathered material of *S. angouya* from four localities: Reserva Privada de Vida Silvestre Urugua-í, Depto. General Manuel Belgrano; Puerto Península, Parque Nacional Iguazú, Depto. Iguazú; Refugio Moconá, A° Oveja Negra and Ruta 2, Reserva de la Biósfera Yabotí, Depto. Guaraní and Reserva de Usos Múltiples Guaraní, Municipio El Soberbio, Depto. Guaraní, Misiones province, Argentina.

This is the first record of *G. ulysi* for *E. russatus*, enlarging the geographical and host range of the species.

***Guerrerostrongylus zetta* (Travassos 1937)**

Site of infection. small intestine

Collection number. MLP-He7350

Host species. *Oligoryzomys nigripes*. CG190

Localities. CAMB, RVSU and PPU

Comments. The morphological characters observed in the specimens agree with the original description and subsequent redescriptions given by Travassos (1937) and e.g. Digiani *et al*. (2012), i.e. synlophe with numerous (ca. 40) subequal ridges, ellipsoidal caudal bursa with hypertrophied and divided at mid-length dorsal ray, very long rays 6, well-sclerotized and usually strongly twisted thin spicules and SpL/BL of 9.8–21.6%.

Guerrerostrongylus zetta was originally described by Travassos (1937) as *Longistriata zetta* from the small intestine of a "rato rapé" (no specific name) in Angra dos Reis, RJ, Brazil. Afterward it was transferred to *Hassalstrongylus* and then to *Guerrerostrongylus* (Durette-Desset; 1971; Sutton & Durette-Desset, 1991). The host list in Brazil comprises *Nectomys squamipes*, *Cerradomys subflavus* (Wagner, 1842), *O. nigripes* and *Galea spixii* (Wagler, 1831), *Akodon cursor* and *E. russatus* (Pinto *et al.* 1982; Gomes *et al*. 2003). Its geographical range was extended to Rio de Janeiro by Simões *et al*. (2011, 2012b) (in *A. cursor* and *O. nigripes*) and to Rio Grande do Sul by de Werk *et al*. (2016) (in *O. nigripes*).

In Argentina, Digiani *et al*. (2012) found *G. zetta* parasitizing *O. nigripes* from Reserva UNLP, Valle del Arroyo Cuña Pirú, Aristóbulo del Valle, and Reserva Privada de Vida Silvestre Urugua-í, Misiones province, Argentina. Based on this material and on the type specimens housed in the Helminthological Collection of the Instituto Oswaldo Cruz (CHIOC), these authors emended the description of the species taking into account the description of the synlophe, and assigned *N. squamipes* as the type host.

***Hassalstrongylus epsilon* (Travassos 1937)**

Site of infection. small intestine

Collection number. MLP-He7344, MLP-He7349

Host species. *Nectomys squamipes*. CG44. *Oligoryzomys nigripes*. CG190

Localities. RVSU and PPU

Comments. The morphological characters observed in the specimens agree with the original description and subsequent redescriptions given by Travassos (1937) and Durette-Desset (1969), i.e. subsymmetrical caudal bursa with poorly developed dorsal lobe, very short spicules, and synlophe with 22 slightly unequal ridges.

This species was formerly described by Travassos (1937) as *Longistriata epsilon*. Durette-Desset (1969) later emended the description of the species based on the type of specimens housed in the Helminthological Collection

of the Instituto Oswaldo Cruz and assigned *Nectomys squamipes* as the type host. Then Durette-Desset (1971) proposed the combination *Hassalstrongylus epsilon.* Subsequent reports of the species in Brazil include those of Pinto *et al.* (1982) in *N. squamipes* from the Goiás State, and Gomes *et al*. (2003) in *N. squamipes* and in *A. cursor* from Rio de Janeiro State.

This is the first record of this species in *O.nigripes* and from Argentina.

Trichofreitasia lenti Sutton & Durette-Desset 1991

Site of infection. small intestine, common bile duct

Collection number. MLP-He7329

Host species. *Akodon montensis*. CG145

Localities. CAMB, RVSU and PPU

Comments. The morphological characters observed in the specimens agree with the original description and subsequent redescriptions given by Sutton & Durette-Desset (1991) and Suriano & Navone (1992), i.e. relatively large body (7–13 mm.), synlophe with 22 ridges stout and oriented perpendicularly to body surface, subsymmetrical caudal bursa with lateral pattern of type 2-2-1, well-developed dorsal lobe with dorsal ray distally divided and short spicules (230-310) in relation to body length.

Trichofreitasia lenti was originally described by Sutton & Durette-Desset (1991) in *Oligoryzomys flavescens* (Waterhouse, 1837) from Buenos Aires province, Argentina. Shortly after, Suriano & Navone (1992) described *Hassalstrongylus multiovatus* in *Akodon simulator* (Thomas, 1916) from Tucuman province, Argentina. Later, Digiani *et al*. (2007) synonymized it with *T. lenti*. This species was also recorded for *A. montensis*, *A. cursor* and *O. nigripes* from Serra dos Órgãos, Rio de Janeiro, Brazil (Simões *et al*. 2011).

This is the first record of this species in Misiones province, Argentina.

Stilestrongylus aculeata (Travassos 1918)

Site of infection. small intestine

Collection number. MLP-He7330

Host species. *Akodon montensis*. CG177

Localities. CAMB, RVSU and PPU

Comments. The morphological characters observed in the specimens agree with the original description given by Simões *et al*. (2014), i.e. synlophe with 19–23 subequal ridges, asymmetrical caudal bursa with larger right lobe, bursal pattern of type 1-4 on the right lobe and 2-2-1 on the left lobe, left ray 2 especially developed, asymmetrical arising of rays 8 and spicules 370–460 long, among other morphometric characters.

This species was originally described as *Heligmosomum aculeatum* by Travassos (1918) from Angra dos Reis, Rio de Janeiro, Brazil. This author later provided the illustration of the caudal bursa, which was not included in the former description (Travassos, 1921). The species was transferred to the genus *Longistriata* Schulz, 1926 (Travassos & Darriba, 1929) and, finally, to *Stilestrongylus* by Durette-Desset (1971) although none of these nomenclatural changes were accompanied by a redescription. Simões *et al*. (2014) recently described the synlophe and provided some morphometrical data for the species. Our specimens were identified as *S. aculeata sensu* Simões *et al.* (2014) because the main diagnostic characters (mainly those of the caudal bursa) corresponded to those described by Simões *et al.* (2014), rather than to those described by Travassos (1918, 1921).

Stilestrongylus aculeata was reported from *Akodon cursor* in Suruí-Magé (Gomes *et al.* 2003) and later from *A. montensis* and *O. nigripes* in Serra dos Órgãos (Simões *et al*. 2011), Rio de Janeiro, Brazil.

This is the first record of this species in Argentina, and so extends its geographical range.

Stilestrongylus lanfrediae Souza, Digiani, Simões, Luque, Rodrigues-Silva & Maldonado, 2009

Site of infection. small intestine

Collection number. MLP-He7340, MLP-He7351, MLP-He7357

Host species. *Euryoryzomys russatus*. CG563. *Oligoryzomys nigripes*. CG190. *Sooretamys angouya*. CG201

Localities. CAMB, RVSU and PPU

Comments. The morphological characters observed in the specimens agree with the original description given by Souza *et al.* (2009), i.e. synlophe with 25–26 subequal ridges, bell-shaped and asymmetrical caudal bursa with strong asymmetry of rays 8 and of branches of dorsal ray, very long and striated spicules, and SpL/BL of 25–29%.

Stilestrongylus lanfrediae was described by Souza *et al*. (2009) in *O. nigripes* from Serra dos Órgãos, Teresópolis, Rio de Janeiro, Brazil. It was also recorded by Simões *et al*. (2011) extending the range of the hosts to *A. cursor* and *A. montensis*.

This is the first record of this species in Argentina, and *E. russatus* and *S. angouya* are new host records.

***Stilestrongylus* n. sp. (1)**

Site of infection. small intestine

Collection number. MLP-He7334

Host species. *Thaptomys nigrita.* CG45

Localities. CAMB, RVSU and PPU

Comments. The genus *Stilestrongylus* was defined by having a markedly asymmetrical caudal bursa, a hypertrophied genital cone and a synlophe with more than 24 cuticular ridges, small and subequal in size (Notarnicola *et al*. 2010). Among the 26 species of *Stilestrongylus* described to date, 25 have been described from Sigmodontinae rodents and 1from a spiny rat (Echimyidae) (Souza *et al.* 2009; Simões *et al*. 2014).

Some of the specimens found in *T. nigrita* in the present study were identified as a new species, differing from those previously described in this genus because of a particular combination of characters, including strong dissymmetry of the bursa, hypertrophy of the common trunk of right rays 2-6, length of dorsal ray and length of the spicules (unpublished data).

***Stilestrongylus* n. sp. (2)**

Site of infection. small intestine

Collection number. MLP-He7351, MLP-He7358

Host species. *Euryoryzomys russatus.*CG561. *Sooretamys angouya.* CG201.

Localities. RVSU and PPU

Comments. Main characteristics of the genus *Stilestrongylus* were mentioned above. Some of the specimens parasitizing *E. russatus* and *S. angouya* were identified as a new species because of the following unique combination of characters: pattern of lateral lobes of bursa, development of dorsal lobe, length of cephalic vesicle, shape and length of spicules and SpL/BL.

All reports of *S. aculeata*, *S. lanfrediae*, *Stilestrongylus* n. sp. (1) and *Stilestrongylus* n. sp. (2) represent the first record of *Stilestrongylus* in Misiones province, and, at the same time, add *E. russatus*, *S. angouya* and *T. nigrita* to the list of hosts of the genus *Stilestrongylus.*

Nippostrongylinae sp. (1)

Site of infection. small intestine.

Collection number. MLP-He7335

Host species. *Thaptomys nigrita.* ROB159

Localities. CAMB, RVSU and PPU

Comments. These specimens show some characters of the synlophe that allow them to be attributed to the Nippostrongylinae, i.e. the number of ridges (more than 13) and the ridges continuous around the body (Beveridge *et al.* 2013). At first, the specimens could not be assigned to any known genus in the subfamily mainly because of having a synlophe with a careen made up of two ridges of dissimilar development and a subsymmetrical caudal

bursa with short dorsal lobe. The presence of a careen makes it similar to the genus *Mazzanema* Digiani, Notarnicola & Paulos, 2013 (monotypic) parasitic in *Holochilus chacarius* Thomas, 1906 (Sigmodontinae). However, other characters of the bursa and the synlophe are different from those of the sole species *Mazzanema fortuita* (Freitas, Lent & Almeida, 1937) and the value of these characters has still to be assessed.

This is the first record of Strongylida in *T. nigrita* together with *Stilestrongylus* n. sp. (1) (see above).

Nippostrongylinae sp. (2)

Site of infection. small intestine

Collection number. MLP-He7342

Host species. *Euryoryzomys russatus*. CG563

Localities. CAMB, RVSU and PPU

Comments. Main characteristics of the Nippostrongylinae were mentioned above. However, these specimens could also be attributed to the Nippostrongylinae and remain under study, though they could not be assigned to any known genus in the subfamily mainly because of having a synlophe with unequal ridges and the largest of them being associated with the lateral fields rather than with the left-ventral and right-dorsal quadrants. This character makes them similar to the species *Malvinema carolinae* Digiani, Sutton & Durette-Desset, 2003, parasitic in *Scapteromys aquaticus* Thomas, 1920 (Sigmodontinae). However, Nippostrongylinae specimens show some differences regarding the synlophe compared to that of *M. carolinae*, namely, the number of ridges and, especially, the inclination of the orientation axis of the ridges with respect to the sagittal axis (see Digiani et. al 2003). The largest ridges associated with the lateral fields is a character of *M. carolinae* but this is not present in rest of the species of the genus *Malvinema* Digiani, Sutton & Durette-Desset, 2003. Consequently, its value as a specific or generic character remains to be assessed for taxon description.

This is the first record of Nippostrongylinae in *E. russatus* for Argentina together with *S. lanfrediae*, *Stilestrongylus* n. sp. (2) and *G. ulysi* (see above).

Order Oxyurida Chabaud 1974

Superfamily Oxyuroidea Cobbold 1864

Family Oxyuridae Cobbold 1864

Subfamily Syphaciinae Railliet 1916

***Syphacia alata* Quentin 1968**

Site of infection. caecum

Collection number. MLP-He7336

Host species. *Thaptomys nigrita.* CG355

Localities. CAMB, RVSU and PPU

Comments. The morphological characters observed in the specimens agree with the original description given by Quentin (1968), i.e. absence of deirids in both sexes, well-developed cervical alae in females, equidistant mamelons, accessory hook of gubernaculum with ornamentation on whole surface, relatively long tail in males, among other morphometric features.

This species was originally described by Quentin (1968) for *N. lasiurus* and recorded for *O. nigripes* and *Sigmodontomys alfari* (Allen 1897) (Quentin 1968, 1969) from Pernambuco, Brazil. In Argentina, Robles (2010) mentions this species parasitizing *T. nigrita* from Balneario Municipal de Aristóbulo del Valle in the stream Cuña Pirú and Caraguatay, Misiones province, and *N. lasiurus* from Finca La Adelita, Laguna Paiva, Corrientes province; Colonia Villafañe, Formosa province; Estación Experimental del INTA Villa Miguel Lanús, Misiones province; Oliveros, Uranga and Maciel in Santa Fe province; and Pergamino and Rojas in Buenos Aires province.

***Syphacia carlitosi* Robles & Navone 2007**

Site of infection. caecum

Collection number. MLP-He7331

Host species. *Akodon montensis*. CG169

Localities. CAMB, RVSU and PPU

Comments. The morphological characters observed in the specimens agree with the original description given by Robles & Navone (2007), i.e. absence of deirids in both sexes, well-developed cervical alae in females, not equidistant mamelons, accessory hook of gubernaculum with ornamentation on lateral edges, relatively long tail in males, among other morphometric features.

This species was formerly described parasitizing *Akodon azarae* (Fischer 1829) from El Colorado, Pirané, Formosa; Colonia Villa Elisa, Colón, Entre Ríos; and Punta Piedras, Punta Indio, Buenos Aires, Argentina (Robles & Navone 2007a), and later recorded for *A. montensis*, *Akodon phylipmyersi* Pardiñas, D´Elía, Cirignoli & Suárez 2005 and *Castoria serrensis* (Thomas, 1902) from different localities in Misiones province, such as Balneario Municipal de Aristóbulo del Valle in Stream Cuña Pirú, Puerto Península, Caraguatay (Robles 2010), and *A. cursor* from Serra dos Órgãos, Río de Janeiro, Brasil (Simões *et al*. 2011).

***Syphacia evaginata* Hugot & Quentin 1985**

Site of infection. caecum

Collection number. MLP-He7343

Host species. *Euryoryzomys russatus*. CG553

Localities. CAMB, RVSU and PPU

Comments. The morphological characters observed in the specimens agree with the original description given by Hugot & Quentin (1985), i.e. prominent (everted) vulva and deirids present in females, equidistant mamelons, accessory hook of gubernaculum with ornamentation relatively short tail in males, among other morphometric features.

This species was described for *Oryzomys* sp. from Belem, Brasil (Hugot & Quentin 1985).

This is the first record for *E. russatus* and from Argentina.

***Syphacia kinsellai* Robles & Navone, 2007**

Host species. *Oligoryzomys nigripes*. CG476

Site of infection. caecum

Collection number. MLP-He7352

Localities. CAMB and PPU

Comments. The morphological characters observed in the specimens agree with the original description given by Robles & Navone (2007), i.e. lacking cervical alae, but the lateral cuticle of the anterior end forms a pair of alae as its thickness increases to include the large deirids in females, equidistant and mamelons, accessory hook of gubernaculum with ornamentation on whole surface, and relatively long tail in males, among other morphometric features.

The species was originally described for *O. nigripes* from Balneario Municipal de Aristóbulo del Valle in the stream Cuña Pirú and RVSU, Misiones province (Robles & Navone 2007b).

Syphacia venteli Travassos 1937

Host species. *Nectomys squamipes*. CG44

Site of infection. caecum

Collection number. MLP-He7346

Localities. CAM, RVSU and PPU

Comments. The morphological characters observed in the specimens agree with the original description and subsequent redescriptions given by Travassos (1937) and Robles & Navone (2010), i.e. presence of cervical and lateral alae and the absence of deirids in both sexes, equidistant mamelons, accessory hook of the gubernaculum very small and without ornamentation, and relatively long tail in males, among other morphometric features.

The species was described for *N. squamipes* from Angra dos Reis, Rio de Janeiro Brazil. Quentin (1969) redescribed the species based on specimens from *Melanomys caliginosus* (Tomes 1860) (Sigmodontinae, Orizomyini) in Valle del Cauca, Colombia. Robles & Navone (2010) redescribed *S. venteli* based on the type specimens and other records of *N. squamipes* from Balneario Municipal de Aristóbulo del Valle in the stream Cuña Pirú and Puerto Península, Misiones province. In addition, Gomes & Vicente (1984) and Gomes *et al*. (2003) recorded this species for *N. squamipes* from different localities of Rio de Janeiro, Brazil.

Order Spirurida

Superfamily Filarioidea

Family Onchocercidae

Subfamily Onchocercinae

Litomosoides navonae Notarnicola 2005

Host species. *Nectomys squamipes*. CG44. *Oligoryzomys nigripes*. CG190

Site of infection. thoracic and abdominal cavities

Collection number. MLP-He7347, MLP-He7353

Localities. CAM and PPU

Comments. The morphological characters observed in the specimens agree with the original description and subsequent redescriptions given by Notarnicola (2005), i.e. buccal capsule with posterior 2/3 strongly cuticularized, external margins of walls irregularly crenate, spicules corresponding to the *sigmodontis* group of species and conspicuous cloacal papillae with 1 pair adcloacal and 5–6 asymmetrical pairs of postcloacal papillae.

This species was originally described by Notarnicola (2005) as a parasite of *N. squamipes* from the Reserva Natural UNLP Valle del Arroyo Cuña Pirú, Cainguás, Misiones, and of *Oligoryzomys chacoensis* (Myers & Carleton 1981), *Holochilus chacarius* and *Akodon azarae* from Estancia La Marcela, El Colorado, Pirané, Formosa province and of *Oligoryzomys fornesi* (Massoia 1973) and *H. chacarius* from Selvas del Río de Oro, Libertador General San Martín, Chaco province, Argentina.

Ecological descriptors

Table 2 shows the results of the ecological descriptors of component communities: total number of parasite specimens, and richness, diversity, equitability and dominance indexes.

TABLE 2. Ecological descriptors of component communities. Values of S: species richness, H′: Shannon and Wiener index, Eq: equitability and D: Dominance.

	A. montensis	*T. nigrita*	*E. russatus*	*N. squamipes*	*O. nigripes*	*S. angouya*
S	8	4	7	5	6	5
H′	1.13	1.03	1.39	0.75	1.06	1.07
Eq	0.55	0.74	0.71	0.47	0.59	0.66
D	0.61	0.58	0.47	0.55	0.48	0.51

The highest value of richness index was observed for *A. montensis* (S=8) and *E. russatus* (S=7) followed by *O. nigripes* (S=6), *N. squamipes* (S=5) and *S. angouya* (S=5). *Akodon montensis* presented the highest total number of parasites (7100) followed by *O. nigripes* with 3300. The rest of species displayed less than 1500.

The H' reached values between 1.03 and 1.39 in all rodents, with the exception of *N. squamipes* that reached 0.75. The equitability index varied between 0.47 and 0.66 with the highest values for *T. nigrita* and *E. russatus*.

The Berger-Parker index of dominance was similar for all host species. Nippostrongylinae was the dominant group within each host species. The highest values were observed for *S. aculeata* from *A. montensis* (D=0.61) followed by *Stilestrongylus* n. sp. (1) from *T. nigrita* (D=0.58) and *H. epsilon* from *N. squamipes* (D=0.55).

TABLE 3. Ecological descriptors of component populations. P: prevalence, MA: mean abundance, MI: mean intensity.

Host species	Parasite species	P	MA	MI
A. montensis	*Platynosomoides* sp.	7	0.3	4.1
n=104	*R.* cf. *akodontis*	44	1.2	2.7
	T. navonae	72	4.3	6
	Eucoleus sp. (1)	7	0.4	5.7
	T. coronatum	4	0.1	1.5
	T. lenti	58	6.2	10.8
	S. aculeata	64	44.8	69.5
	S. carlitosi	49	18	36.7
Brucepattersonius sp.	*Eucoleus* sp. (2)	43	0.4	2
n=7				
T. nigrita	*T. navonae*	16.7	0.3	2
n=6	*Stilestrongylus* sp. (1)	83.3	19	22.8
	Nippostrongylinae indet. (1)	83.3	4.7	5.6
	S. alata	16.7	4.7	28
E. russatus	*Trichuris* sp.	6.7	0.1	1
n=15	*T. coronatum*	6.7	0.1	1
	G. ulysi	33.3	10.7	32
	S. lanfrediae	13.3	6.7	50
	Stilestrongylus sp. (2)	73.3	49.3	67.3
	Nippostrongylinae indet. (2)	73.3	17.3	23.6
	S. evaginata	20	20.5	102.3
N. squamipes	*H. epsilon*	100	285	285
n=3	*T. cf. travassosi*	33	0.7	2
	S. venteli	66.7	223.3	335
	L. navonae	100	5	5
O. nigripes	*T. coronatum*	3.7	0.2	6
n=27	*H. epsilon*	26	1.8	6.9
	G. zetta	96.3	45.9	47.7
	S. lanfrediae	85	58.7	68.9
	S. kinsellai	33	15.4	46.2
	L. navonae	3.7	0.2	5
S. angouya	*T. baine*	50	0.7	1.3
n=6	*T. coronatum*	16.7	0.2	1
	G. ulysi	83.3	6.8	8.2
	S. lanfrediae	66.7	15.7	23.5
	Stilestrongylus sp. (2)	83.3	24.2	29

Table 3 details P, MI and MA of the helminths registered. The results for individuals of *A. montensis* and *O. nigripes* were obtained from RVSU and PPU.

The highest values of P, MA and MI corresponded to Nippostrongylinae followed by Syphacinii. Exceptionally, *T. nigrita*, *N. squamipes* and *E. russatus* showed the highest values of MI in Syphacini, followed by Nippostrongylinae.

Discussion

Prior to this study, Navone *et al*. (2009) reported 23 species of helminths from *A. azarae*, *Deltamys kempi* Thomas, 1917, *O. nigripes*, *O. flavescens*, *O. rufus* and *Scapteromys aquaticus* Thomas 1920 in the Delta and Paraná Islands ecoregion, Argentina.

The helminth community of seven of the 18 cricetid species registered for the Atlantic Forest were studied. To date, only two parasitological surveys by Gomes *et al.* (2003) and Simões *et al*. (2011) have been carried out in this ecoregion on an assemblage of four and three cricetid species in Brazil, with nine and 18 helminths species reported, respectively. In this context, 25 species of helminths were reported in this study, constituting the most diverse parasitic assemblage described for the Atlantic Forest ecoregion and for Argentina (Table 1).

Several parasitic species were found in more than one host species. Among them, *T. coronatum* was found in four host species, followed by *S. lanfrediae* parasitizing three host species. The rest of species were found in one or two host species (see Table 1). It is to be noted that of the seven helminth species that were common to more than one host species, only *T. coronatum* was present in the two studied tribes, Akodontini and Oryzomyini. In this sense, some degree of phylogenetic conservationism could be suggested since closely related host species tend to harbour more similar parasite faunas than more distant host species, as suggested by Poulin (2014).

The assemblage of helminths studied in this paper shows similarities in the composition of species regarding those reported in Brazil by Simões *et al*. (2011): *A. montensis* S=12 and *O. nigripes* S=12; and by Gomes *et al.* (2003): *E. russatus* S=1, *N. squamipes* S=3 and *O. nigripes* S=2; and, in Argentina, by Navone *et al*. (2009): *O. nigripes* S=4 (see Table 2). These results could be associated with the breadth and composition of the diet of hosts, as well as with the environmental characteristics of each area (Poulin 2014).

In this context, numerous helminths that were reported parasitizing *O. nigripes* were not found in the present survey, therefore indicating a possible association of each parasite species with environmental factors, absence of vectors, intermediary hosts or primary definitive hosts, e.g.: *Canaania obesa* Travassos 1944, *Taenia taeniformis* (Batsch, 1786), *Raillietina* sp., *Stilestrongylus eta* (Travassos 1918), *Litomosoides odilae* Notarnicola & Navone 2002, *Avellaria* sp. and *Hassalstrongylus hoineffae* (Durette-Desset, 1969), in Brazil and; *Echinoparyphium scapteromae* (Sutton, 1983), *Litomosoides bonaerensis* Notarnicola, Bain & Navone 2000 and *Stilestrongylus flavescens* Sutton & Durette-Desset 1991, in Argentina (Durette-Desset 1969; Pinto *et al*. 1982, Navone *et al.* 2009; Simões *et al.* 2011).

This study provides valuable results not only concerning the specific composition of the assemblage of sigmodontine rodents of the Argentine Atlantic Forest, but also ecological data regarding the parasite distribution of each studied host species, which can form the basis for future surveys.

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